Mechanical Behaviour of Materials
Prof. S. Sankaran
Department of Metallurgical and Materials Engineering
Indian Institute of Technology - Madras

Lecture - 17
Introduction to Dislocations – V

Hello, I am Professor S. Sankaran in the Department of Metallurgical and Materials Engineering. Hello everyone welcome to this NPTEL course and let us continue our discussion on dislocations. If you recall what we have discussed in the last lecture we started with geometry of dislocations and we looked at different aspects of describing the dislocation in terms of slip factor and its orientation with respect to crystal geometry.

And we also looked at the energy of dislocation later and then detailed description on a stress field around this dislocation. And we also looked at force on a dislocation or other forces on dislocation. And we found that these forces could be either within the crystal or it could be an external stress or it could cause by another dislocation itself. And we also started looking at various dislocation reactions.

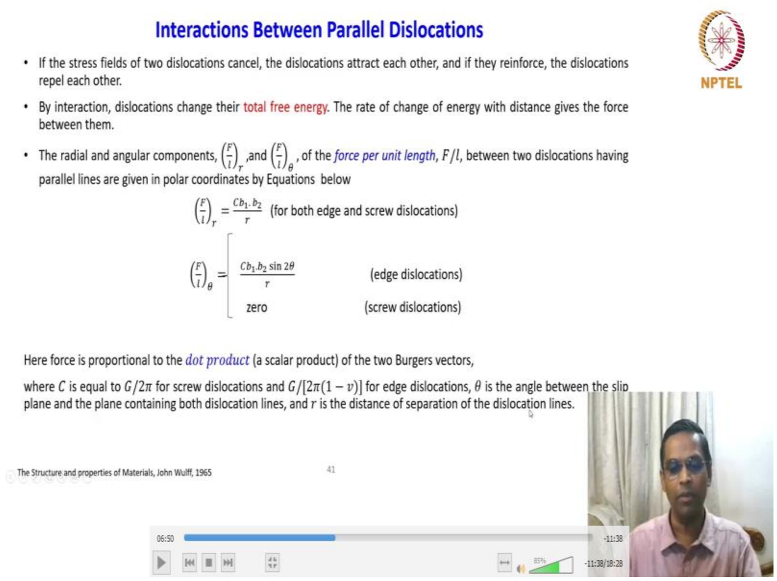
That in terms of whether there is even a dislocation can be associating to two partial dislocations or two partial dislocations can combine to form again a dislocation based on Frank's rule. And later we just moved on to a concept called stacking fault about this through this partial dislocations were a partial dislocation a typical nature is a/6 [112] type of dislocation if it pass through for example an FCC lattice.

And it alters the stacking that also we have seen in terms of vectorial form as well as the some nice schematics how the faulty region is visualized and so on. And the stacking fault energy is measured milli joules per meter square because dislocation we measure energy per unit length this is energy per unit area because the faulty region occupies definite amount of region which just measured.

And we have also seen based on the how the Frank's rule is useful to find out for a given dislocation whether it will dissociate ordered and so on. And later we also started looking at how the dislocation moves we started with edge dislocation how it moves with in response to shear stress and then we also found that the elastic strain energy which is stored in the system has to balance the atom which is moving away from this dislocation core.

And which act against the restoring of the neighbouring atom to this equilibrium position and so on. And we also started looking at interactions of two dislocations. And we just looked at how the two dislocations of similar sign will react with each other or opposite sign how they are get each other.

(Refer Slide Time: 04:05)



So, we are going to continue that idea today, so interactions between two parallel dislocations. So, we will just look at the concepts which we have already seen in the last class. It will be a slightly redundant here but it is still looking it is kind of a revision in the stress field of two dislocations cancels, the dislocations attract each other and if they reinforce the dislocation repel each other. So, by interaction, a dislocation changes their total free energy.

And we are looking at the rate of change of energy with a distance give the force between them please understand that we are looking at the rate of change of energy with a distance of a dislocation. So, if you look at the force in a polar coordinates the radial and angular components that is $\left(\frac{F}{l}\right)_r$ and $\left(\frac{F}{l}\right)_\theta$ of the force per unit length F/l between two dislocations having parallel lines or given in polar coordinates by the equation below.

What is this equation? this is equation

$$\left(\frac{F}{l}\right)_r = \frac{Cb_1b_2}{r}$$

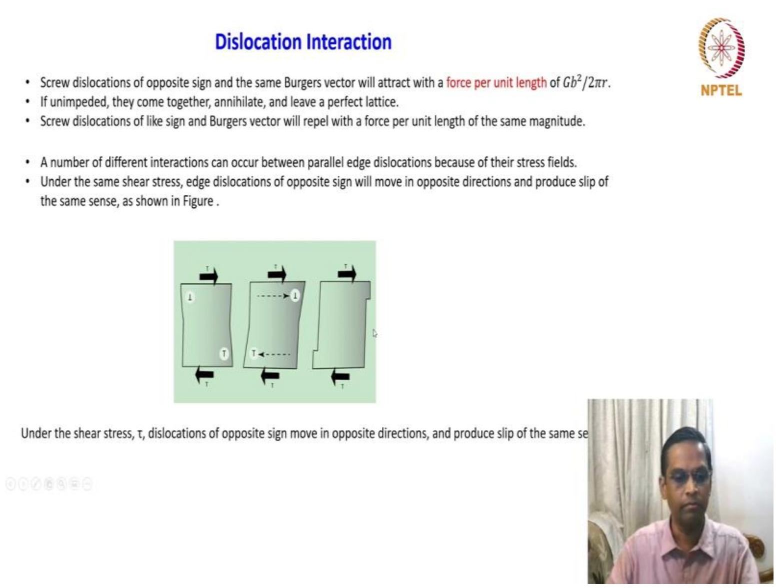
this is valid for both edge and screw dislocations. So, the angular component is given by

$$\left(\frac{F}{l}\right)_\theta = \frac{Cb_1b_2\sin 2\theta}{r}$$

this is for edge dislocation which is 0 for screw dislocation. What is C here? As we mentioned in the previous class the force is proportional to the dot product here because we assumed that it is confined to a single plate.

So, the scalar product is value get of two Burger's vectors C is a constant which is equal to G/2π for a screw dislocation and G/2π(1-υ) for a edge dislocations. So, we have enough background to recognize these types of lasting constant modification because of the plane problems that we have already mentioned twice. So, theta is the angle between the slip plane and the plane containing both dislocation lines, r is the distance of separation of dislocation lines. So, the whole thing we have already seen once but yeah it is nice to recall all these once again.

(Refer Slide Time: 07:00)

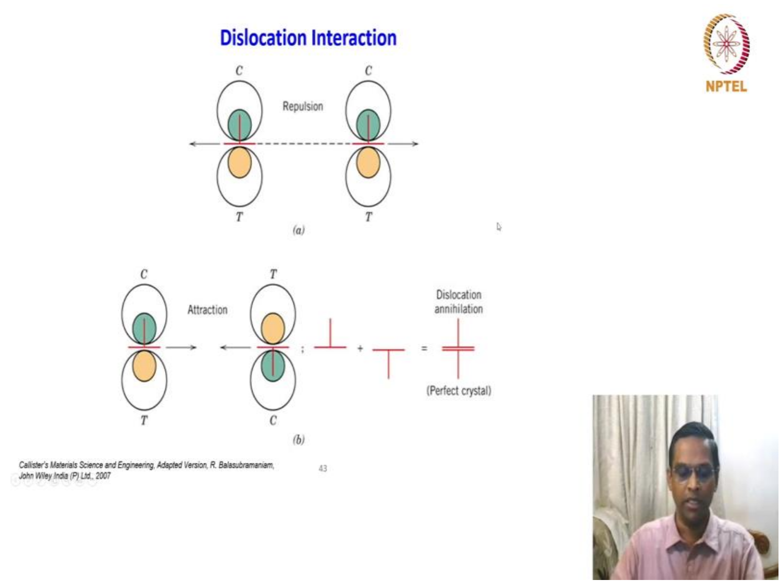


And we have already seen that the screw dislocations of opposite sign and the same Burger's vectors will attract with the force per unit length of $Gb^2/2\pi r$. If unimpeded they come together annihilate and leave the perfect lattice. Screw dislocation of like sign and the Burger's vector will repel with force per unit length of the same magnitude. So, these are general guidelines but with this background we can think of the number of different interactions that can occur between parallel edge dislocations because of their stress fields.

We have to remember that having gone through all this details of the stress fields we, appreciate that the stress fields around the edge dislocations are quite complex. And if you recall the upper half plane this whole crystal is subjected to hydrostatic compression the bottom of is subjected to hydrostatic tension just to recall this. So, under the same shear stress edge dislocations of opposite sign will move in opposite directions and produce a slip of the same sense.

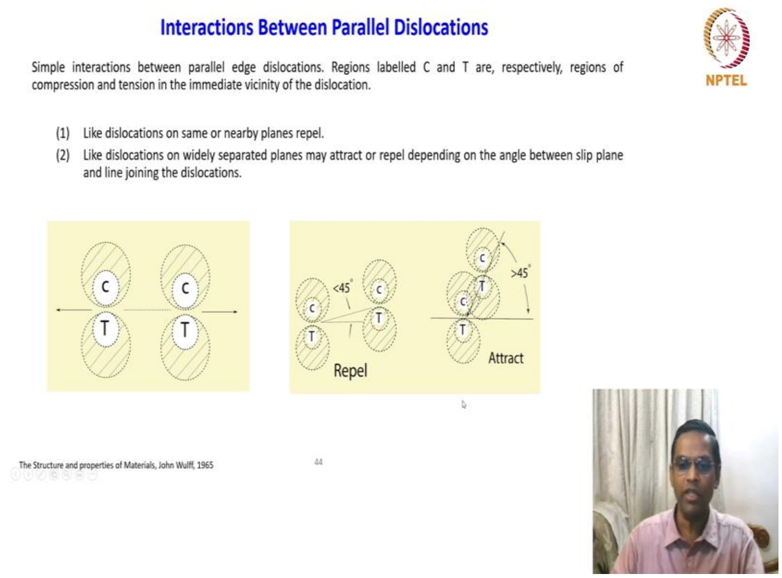
What is that means? Suppose if you have a two edge dislocations of opposite sign like this and the shear stresses applied this direction and then they will move in opposite direction and then the lead the crystal then it is the steps a slip step is left on crystal or a lattice.

(Refer Slide Time: 09:04)



And this is one nice schematic which shows that you know dislocation of same sign the repel each other; this contours nicely convey that the kind of stress fields around this rotation. This is compression, this is tension and the two dislocations of the opposite sign they get attracted you know why and yeah this is nice symbolism. And then what you really get us a perfect crystal, this is called a dislocation annihilation. This be very frequently the will use this term when we involve the dislocation dynamics as a consequence of either deformation or heat treatment or any processing conditions.

(Refer Slide Time: 10:05)



Now we will look at some specific and interesting examples what you are seeing is here two simple interactions you will see between parallel to edge dislocations regions labeled C and T are respectively regions of compression and tension in this schematic same edge dislocations and they are trying to repel each other, the repulsion is always not going to happen like dislocation on same or nearby planes repel.

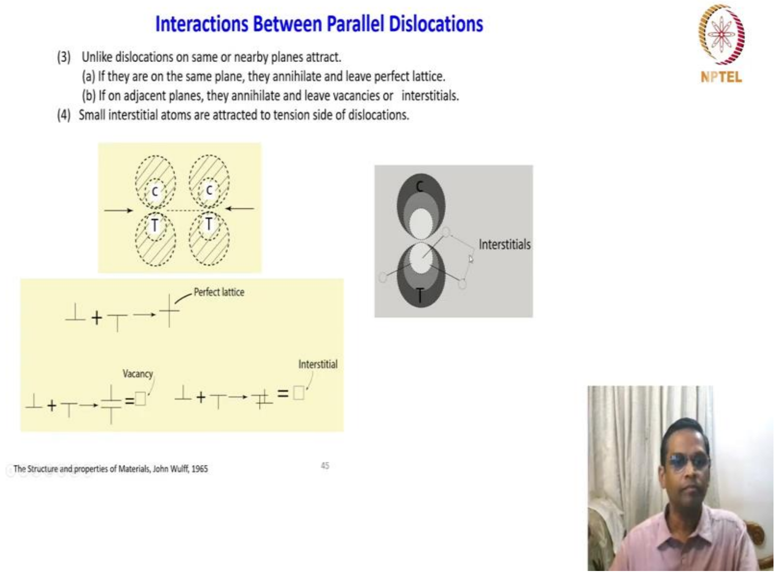
Here we are considered that these two dislocations edge dislocation like in the same plane are nearby there are two things they try to repel but that is not always the case. What is the other possibility? Like dislocations on widely separated planes may attract or repel. So, this is important we have to just remember this point very important point and it will lead to a very logical conclusion you just see.

So, if the like dislocations are widely separated they may get attract or repel depending upon the angle between the slip plane and the line join the dislocations. So, how do we understand this to understand this only this schematic is brought here, suppose this is one dislocation and this is another dislocation the angle between these two, angles between slip plane and the line joint the dislocation so this is line join dislocations slip plane.

Which is less than 45 degree then it is still going to repel and if this is going to be more than 45 degree then you see that the situation is quite different, what happens is that if the angle becomes more than 45 degrees then you see that you know the shift of the dislocation is quite high and then what is that you are seeing here? You are seeing that the compression and tension field forces are coming close together.

So that means for they will try to attract each other. So, this is nicely shown in this schematic and then now you recall if these kinds of arrangements are there and this is exactly we have seen in the yesterday's lecture that these types kind of edge dislocations will try to align one over the other to form a stable configuration or low angle grain boundaries or something like that. So, this is the basis of that so this is very important.

(Refer Slide Time: 12:58)



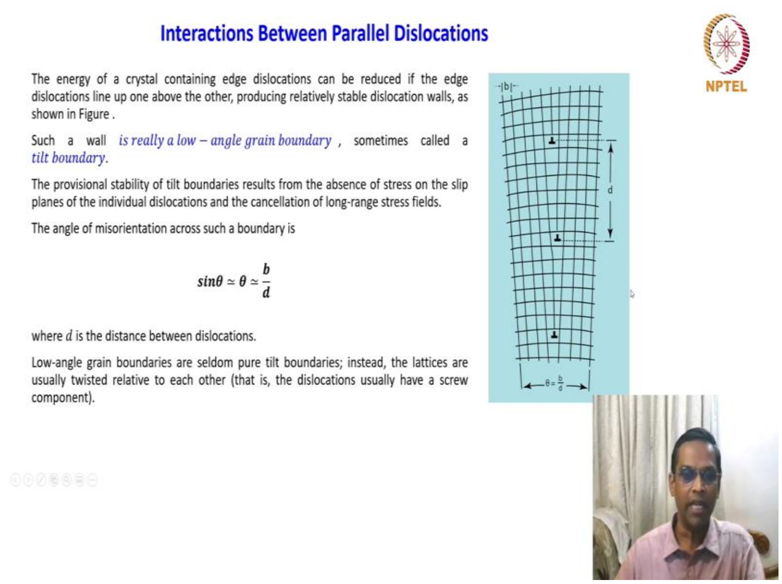
So, what is the next one unlike dislocations on the same a nearby plane attract? So, this is quite obvious this schematic should be wrong because the unlike means the T should be up and C should be down. So, there is a correction here and because they should compare this symbolism here this is positive dislocation, this is negative dislocation so it should be rotated 90 degree. So, there is a correction here.

So, if they combined together then it forms a perfect lattice, but there is another interesting idea what is that idea if no adjacent planes they annihilate and lever vacancies or interstitials very important what is that if they are not moving on the same plane then and they will annihilate but leave the vacancies here you see this one the center. So, it forms a vacancy here either it can form a vacancy or it can form an interstitial.

So, what is the difference between interstitial and vacancy? Vacancy you understand there is no atom in your the wide is kept empty. On the other hand interstitial means small solute atoms which get in traveling this for example carbon iron is very classical example familiar to everybody nitrogen carbon even sometimes Boron people refer this as interstitial iron lattice. So, the solute atoms should be significantly smaller as compared to solvent atom in a solid solution.

So, this kind of motion will facilitate either to form a vacancy or an interstitial. So that is what is shown here all we have seen that in the previous lecture that these forces on or stress fields around the dislocation attracts both solute atoms right substitutional as well as interstitial. So, primarily this interstitial being very small than it get attracted much easier. So, this is exactly we have just said.

(Refer Slide Time: 15:49)



So, the energy of the crystal containing edge dislocations can be reduced, if they edge dislocations line up one above the other produces relatively stable edge dislocation walls as shown. So, this we have already seen yesterday but this is a schematic which depicted most of the physical metrology textbook the formation of a low angle train boundary shown like this and you see that Burger's vector and the theta is b/d the distance between the two edge dislocations in the vertical axes d.

Such as wall is really a small angle grain boundary sometimes called tilt boundary, another name for this tilt boundary. The provisional stability of the tilt boundaries results from the absence of stress on the slip planes of the individual dislocations and the cancellation of long range stress fields. So, the stress filed cancellation what we have understood it is not pertaining to this one localized event it is a cancellation of long range stress fields.

When it comes to these kind of a stable low angle boundary this kind of arguments are valid. The angle of misorientation across such boundary is given by this since being the ϴ is being small it is considered ϴ instead of sinϴ is b/d. So, low angle the grain boundaries are seldom pure tilt boundaries instead the lattices are usually twisted relative to each other that is the dislocations usually have a screw component.

So, these kinds of you know variations will always be there in real systems. And we just brought this idea just to because it gives a very nice example how this the stress fields around this dislocation how will get annihilate and how it forms a stable configuration.